An Enhanced Energy Efficient Chain-based Routing Protocol for Wireless Sensor Networks

Shilpa Thakur[1] Kanika Sharma[2]
[1]M.E. Student [2]Assistant Professor
[1,2]ECE Department
[1]National Institute of Technical Teachers Training and Research, Chandigarh, India.

Abstract— Wireless sensor networks has come out as an important computing platform.A wireless sensor network is an aggregation of nodes organized into a cooperative network.Each node consists of processing capacity. Energy conservation and maximization of network lifetime are commonly recognized as a key challenge in the design and implementation of wireless sensor networks.

In this paper, we propose an Enhanced Energy Efficient Chain-based Routing Protocol (EEECRP) for wireless sensor networks to minimize energy consumption and transmission delay.EEECRP organizes sensor nodes into a set of horizontal chains and a vertical chains. Chain heads are elected based on the residual energy of nodes and distance from the header of upper level. In each horizontal chain, sensor nodes transmit their data to their own chain head. EEECRP also adopts a chain-based data transmission mechanism for sending data packets from the chain heads to the base station. The simulation results shows that EECRP outperforms PEGASIS , ECCP and EECRP in terms of network lifetime, energy consumption.

Keywords: Wireless sensor network, Hierarchical routing protocol, Enhanced Energy efficient Chain-based routing.

I. INTRODUCTION

The rapid advancement in micro-electro-mechanical systems (MEMS) and low-power wireless communication have enabled the deployment of large scale wireless sensor networks [1].The emerging field of wireless sensor network combines sensing, computation, and communicationinformation and then transmit report messages to a remote base station [2]. The base station aggregates and analyzes the report messages received and decides whether there is an unusual or exceptional event occurrence in the deployed region.

Energy efficiency has been known as the most important issue in the research of wireless sensor networks. Hierarchical techniques have emerged as a popular choice for achievingenergy efficiency in wireless sensor networks[3]. Many of the hierarchical routing protocols proposed by researchers have used clustering approach for routing in wireless sensor network and a few hierarchical routing protocols use chain based data transmission mechanism in wireless sensor network.chain based routing is becoming more and more efficient in WSNs[4].WSNs consist of large number of sensor nodes which are small in size, in expensive and battery powered. These WSNs can be used in various applications such as Military surveillance, environment monitoring, border protection, health care monitoring, and weathermonitoring.These applications require data without delay and energy consumed by them should be small. WSNs are deployed in harsh environment. Since it is not possible to replace or charge battery of sensor nodes, so it is desirable to design communication protocols such that energy source is used effectively and the delay in the network in minimum.

II. LITERATURE

A sensor network is defined as being composed of a large number of nodes which are deployed densely to monitor environmental conditions in remote areas. Each of these nodes collects data and its purpose is to route this information back to a sink. The network must possess self-organizing capabilities since the positions of individual nodes are not predetermined [4]. Cooperation among nodes is the dominant feature of this type of network, where groups of node operate to disseminate the information gathered in their vicinity to the user.

None of the studies surveyed has a fully integrated view of all the factors driving the design of sensor networks and proceeds to present it so WSNs.Communication architecture and design factors to be used as a guideline and as a tool to compare various protocols [4]. After surveying the literature, this is our impression as well and weinclude it in the open research issues that canexplored for future work. The surveyed design factors for WSN are listed as:

1) *Production Cost:*
The production cost of a sensor node should be such that the overall cost of deploying wireless sensor networks should be cheaper than traditional sensors. The cost of a single sensor should not be less the US 1dollar.

2) *Power Constraints:*
Large scale WSNs have extremely low energy and power at their disposal so routing protocol should be designed in such a way that transmission and reception after data is fully justified.

3) *Speed:*
Sensor nodes form a chainIn each gathering round every node sends its data to its neighbor in the chain closer to the sinkData in each node are aggregated the final node sends the aggregated data to the sinkEnergy savings but also increased delay.

4) *Fault Tolerance*
Individual nodes are prone to unexpected failure witha much higher probability than other types of networks. The network should sustain informationdissemination in spite of failures.

5) *Scalability:*
Number in the order of hundreds or thousands. Protocols should be able to scale to such high degreeand take advantage of the high density of suchnetworks.

6) *Hardware Constraints:*
A sensor node is comprisedof many subunits (sensing, processing, communication, power, location Finding system,

power scavenging and mobilize). All these units combined together must consume extremely low power and be contained within an extremely small volume.

B. Related Work:

Recently, a lot of hierarchical routing protocols for reducing energy consumption of wireless sensor nodes have been developed. In this section, some of the hierarchical routing protocols in wireless sensor networks are reviewed.

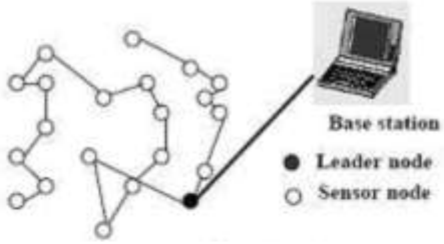

Fig.1: Formation of a chain in WSN [5]

PEGASIS [6] is an improvement of the LEACH protocol. The main idea in PEGASIS is to form a chain among sensor nodes so that each node receives from and transmits to a close neighbor. The gathered data move from node to node, get fused and eventually a designated node transmits them to the base station. In PEGASIS, the chain construction is done in a greedy fashion with the assumption that all the nodes have global knowledge of the network. PEGASIS outperforms LEACH by eliminating the overhead of dynamic cluster formation, minimizing the distance non-leader nodes must transmit, limiting the number of transmissions and receiving among all nodes and using only one transmission to the base station per round.

Chain-Cluster based Mixed routing (CCM) algorithm for wireless sensor networks [7], which divides a wireless sensor network to a few chains and a cluster. CCM algorithm is run in two stages. In the first stage, sensor nodes in each chain transmit data to their own chain head using the chain based routing. In the second phase, all the chain heads form a cluster and send the data, which are fused from their own chains, to a voted cluster head. Finally, the cluster head further fuses data and transmits them to the remote base station.

In the setup phase, clusters are generated and then, in the steady state phase, a spanning tree is constructed for sending aggregated data to the base station. Only the root node of this tree can directly communicate with the base station.

In [8], an Energy Efficient Cluster-Chain based Protocol (ECCP) was proposed for wireless sensor networks. The main goal of ECCP is to distribute energy load among all sensor nodes in order to minimize energy consumption in wireless sensor networks. ECCP organizes sensor nodes into clusters and constructs a chain among the sensor nodes within each cluster. Furthermore, ECCP forms a chain among the cluster heads. In ECCP, cluster heads are elected in a distributed way based on residual energy of nodes, distance from neighbor nodes and number of the neighboring nodes. In ECCP, each node maintains a neighborhood table to store the information about its neighbors. Each round of this protocol consists of clustering phase, chain formation phase and data transmission phase. In ECCP,clustering phase is not performed in each round and sensor nodes use residual energy levels to select new cluster heads for the next round. If any sensor node dies in the cluster, the cluster head sends a message to the base station and informs it that the sensors should hold the clustering phase at the beginning of the upcoming round. ECCP uses a hybrid clustering approach for minimizing energy consumption.

ECCP was extended for time critical applications (ECCPTC) to reduce transmission delay of time critical data [9]. In ECCPTC, the nodes react immediately to sudden changes in the value of a sensed attribute. ECCPTC considers higher priority for time critical data compared with non-time critical data so that time critical data are immediately transmitted to the base station. ECCPTC uses a threshold value for reducing transmission delay of time critical data. If the sensed data value by a sensor node is equal to or greater than threshold value, the sensed data are considered as time critical data and should be immediately transmitted to the base station.

III. ASSUMPTIONS AND RADIO ENERGY MODEL

N sensor nodes are uniformly deployed over a vast field of WSN and considered for continuously monitoring the environment. The following assumptions are assumed for the sensor network.

– Nodes are dispersed randomly following a uniform distribution in a 2-dimensional space.
– The base station is considered a powerful node with enhanced communication and computation capabilities with no energy constraints.
– All sensor nodes in the network are heterogeneous andEnergy-constrained.
– Links are symmetric. A node can compute the approximate distance to another node.

The energy expended to send a k-bit message over a distance d for each sensor node is as in

$$E_{Tx}(k,d) = \begin{cases} kE_{elec} + k\varepsilon_{fs}d^2 & ,d < d_0 \\ kE_{elec} + k\varepsilon_{amp}d^4 & ,d \geq d_0 \end{cases} \quad (1)$$

where E_{elec} is the amount of energy consumed in electronics and ε_{amp} and εfs are the energy consumed in amplifiers.Based on the received signal strength if the transmitting power is known.

The energy expended in receiving a k-bit message is:

$$E_{Rx}(k) = kE_{elec} \quad (2)$$

The energy expended for aggregating m data packets to a single packet is as follows in Eq. (3).

$$E_{fuse}(m,k) = m * k * E_{DA} \quad (3)$$

IV. EEECRP- THE PROPOSED PROTOCOL

In PEGASIS [6] that is a chain based routing protocol for wireless sensor networks, a chain is formed among the sensor nodes so that each node receives from a previous neighbour and transmits to a next neighbour. PEGASIS significantly induces a much longer data transmission delay because of the large number of hops in a long chain. In ECCP [8] that is a cluster-chain based routing protocol for wireless sensor networks,sensor nodes are organized into clusters. When a sensor node dies in the cluster, ECCP suffers from cluster formation overhead. ECCP increases transmission delay compared with LEACH. In ECCP, each node maintains a neighbourhood table to store information of its neighbours that causes waste of memory space of sensor nodes. In ECCPTC [9] that is a cluster-chain based routing protocol for wireless sensor networks, sensor nodes react immediately to sudden changes in the value of a sensed attribute. ECCPTC considers higher priority for time critical data compared with non-time critical data so that time critical data are immediately transmitted to the base station. In ECCPTC, transmission delay of non-time critical data is increased. The main drawbacks of ECCP and ECCPTC are the higher overhead associated with forming clusters when a sensor node dies in the cluster. Also, ECCP and ECCPTC use a complex hybrid clustering approach for reducing energy consumption. In order to avoid these situations, we propose an Enhanced Energy Efficient Chain-based Routing Protocol (EEECRP) for wireless sensor networks to minimize energy consumption and transmission delay. The proposed protocol organizes sensor nodes as a set of horizontal chains and a vertical chain. In each chain, a node is selected as chain head. For selecting the chain heads in horizontal chains, EEECRP considers residual energy of nodes and distance of nodes from the header of upper level that does not need to reselect leader of the vertical chain. This causes time and energy saving. In each horizontal chain, sensor nodes transmit their data to their own chain head based on chain routing mechanism. EEECRP adopts a chain based data transmission mechanism for sending data packets from the chain heads to the base station. EEECRP does not use a complex hybrid approach for reducing energy consumption as ECCP.

In the proposed protocol, the network is divided to a set of strips as shown in Fig.2. It is assumed that "h" is height of each strip and there are "k" strips in the sensor network, computed by "k=L/h", where "L" is length of wireless sensor network. In each strip, a chain is formed among the sensor nodes and a chain head is selected. In order to balance energy consumption among all sensor nodes in the network, the chain head's role should be rotated among the sensor nodes to prevent their exhaustion.

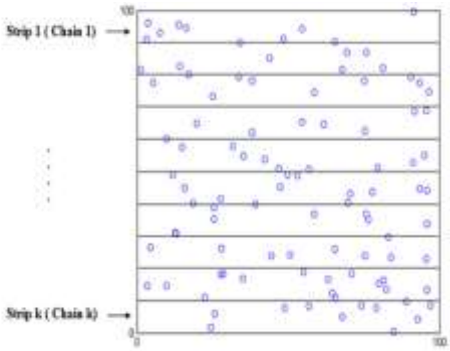

Fig. 2: A sensor network with k number of chains

A. Formation of horizontal chains

After the selection of chain heads, the base station applies the greedy algorithm used in PEGASIS to make a chain among the sensor nodes in each strip (horizontal chain) so that each sensor node receives data from a previous neighbor, aggregates its data with the one received from its previous neighbor and transmits the aggregated data to the next neighbor.The chain is formed from the furthest to the nearest node from the chain head**.**

B. Formation of a Vertical Chain

EEECRP creates a chain among the chain heads which is called vertical chain. The selection of chain heads in horizontal chains is done in such a way that does not need to reselect the leader of the vertical chain and chain head of strip 1 acts as the leader of chain heads so that all the chain heads send data to the leader node through the chain. lastly the leader node aggregates data and transmits them to the base station. This saves most of the chain heads from the high power transmissions to the distant base station and protects them from early exhaustion.Once the chains are formed, the base station broadcasts a message that contains the chain and chain head ID for each node. If a node's chain head ID matches its own ID, the node is a chain head.

C. Transmission of data:

The data transmission phase is divided into several frames and sensor nodes transmit and receive data at each frame. Data transmission phase consists of two stages:

1) Data Transmission among Sensor Nodes in Horizontal Chains

For gathering data in each frame, sensor nodes in each chain transmit their data to their own chain head using the chain based routing. EECRP uses a simple control token passing approach initiated by the chain head to start data transmission from the ends of the chain. The cost is very small since the token size is very small. The two end nodes in a chain transmit data and tokens to their individual neighboring nodes in parallel. Each sensor node receives data and token from previous neighbor, aggregates the data with its own data and transmits aggregated data and token to the next neighbor in the chain. The data are transmitted in an alternative way until all the data are transmitted to the chain head node.

2) Data Transmission among Chain Heads in the Vertical Chain

In this stage, base station generates a token and transmits it to the end chain head node in the vertical chain. Each chain head aggregates its neighbor's data with its own data and transmits aggregated data to the next neighbor in the vertical chain. Finally, the aggregated data are delivered to the base station by the leader node in the vertical chain

V. SIMULATIONS AND RESULTS

To evaluate performance of EEECRP discussed in the previous section, these simulations are presented by MATLAB and its performance is compared with other protocols such as, PEGASIS,EECRPand ECCP. This section describes performance metrics, simulation setup and simulation results.

A. Performance Analysis:

- The following parameters are used to capture performance of the proposed routing approach and compare it with other protocols.
- Network lifetime: The performance analysis is done to evaluate the network lifetime.

– Energy consumption: The total energy consumed by the nodes in receiving and sending the data packets.

B. Simulation Setup

The simulations are carried out with a random network topology with 100 sensor nodes randomly distributed in the monitoring area with the size of 100 m × 100 m. The base station locations are varied at (0,0), (50, 50) and (50,175). The basic parameters for these simulations are shown in Table 1.

Parameters	Value
Network size	(0,0) to (100,100)
Number of nodes	100
Base station location	(0,0),(50,50), (50,175)
Data packet size	1000 Bytes
Control packet size	40 Bytes
Initial energy of nodes	0.4 J
Height of each strip (h)	10 m
P_{Ch}	0.1
Cluster radius r	15 m
E_{elec}	50 nJ/bit
E_{fs}	100pJ / bit /m
ε_{amp}	0.0013 pJ / bit /m
E_{DA}	5 nJ/bit/signal

Table 1. Simulation parameters

C. Simulation Results :

1) Network Lifetime

Fig. 4 shows the total number of nodes that remain alive over the simulation runs with base station location Table 2 that EECRP has better performance than LEACH and PEGASIS in terms of network lifetime with different locations of the base station. The time of the last node to die in EECRP is longer than other protocols and sensor nodes remain alive for longer time. This is mainly because most of the nodes transmit to their nearest neighbors in the chain. For selecting the chain heads inhorizontal chains, EECRP also considers residual energy of nodes and distance of nodes from the header of upper level that eliminates the need for reselecting leader of the vertical chain**.**

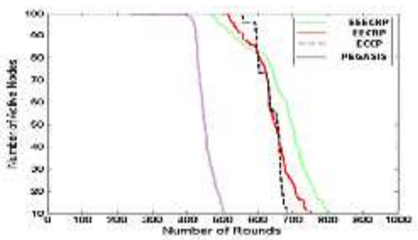

Fig. 3 The profile of network lifetime for each scheme

The simulation results show that:

The Fig.3 shows the possible outcomes of all the existing schemes along with the proposed scheme. The networklifetime is much higher and hence is more efficient in comparison to others. This is due to formation of chains in horizontal and vertical fashion and selection of chain head on the basis of residual energy chain-based data transmission mechanism for sending data packets from the chain headsto the base stationnetwork. The curve of the proposed algorithm decays with clear steps, and is steep to a great extent which means that the consumption of energy among nodes in the network is less, thereby resulting in increased lifetime of network.

2) Energy Consumption

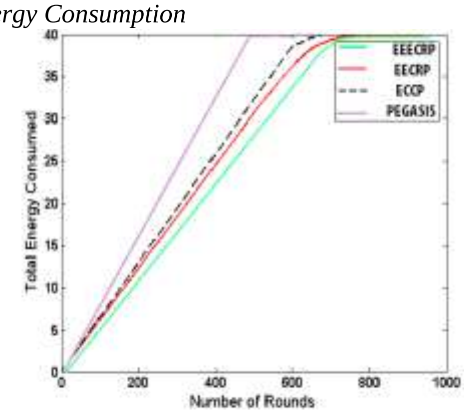

Fig.4: The energy consumption of for each scheme in the network

Fig. 4 demonstrates the energy consumed by all nodes during the simulation runs with base station location. Fig. 4 shows the average energy consumed per round with different locations of the base station. It is obvious that EEECRP uses less energy compared with other protocols with different locations of the base station. LEACH consumes more energy because the cluster heads collect data from sensor nodes and transmit the data directly to the base station while, in EECRP, most of the nodes transmit only to their nearest neighbour in the chain. Moreover, instead of data transmission by multiple chain heads directly to the distant base station, only one chain head transmits data to the base station. EEECRP has better performance than PEGASIS. This is mainly because the chains in EEECRP have smaller length than the single chain in PEGASIS, which reduce the amount of data to be aggregated and propagated along the chain and result in more savings in the energy consumption of the nodes. EEECRP also has better performance than EECRP and ECCP, which is mainly due to higher cluster formation overhead in ECCP when a sensor node dies in the cluster.

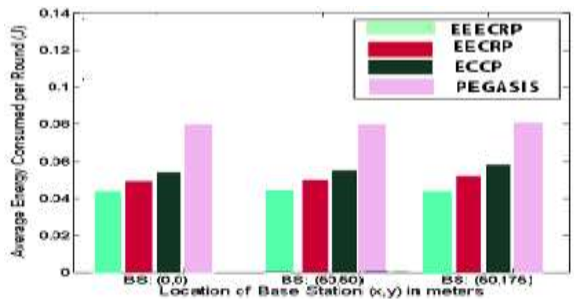

Fig.5 Average energy consumed per round with BS locations at (0, 0), (50, 50) and (50,175)

VI. Conclusion

In this paper, we have proposed an Enhanced Energy Efficient Chain based Routing Protocol (EECRP) for remote sensor systems. The primary objective of EEECRP is to minimize energy consumption. EECRP can meet both prerequisites for a brief reaction and vitality sparing applications. EECRP sorts out sensor hubs into a set of flat chains and a vertical chain so that every sensor hub gets from a past neighbor and transmits to the following neighbor. Moreover, EECRP enhances the information transmission component from the bind heads to the base station by means of building a chain among the chain heads. By binding the hubs in the system, EECRP offers the focal point of little transmit separations for most of the hubs and hence encourages them to be operational for a more drawn out time of time by saving their constrained vitality. Recreation results exhibit that the proposed convention essentially beats PEGASIS, ECCP and EECRP as far as system lifetime, energy consumption. Remote sensor system is a dynamic examination zone.

ACKNOWLEDGEMENT

I am highly grateful to Mrs. Kanika Sharma, Assistant Professor at NITTTR Chandigarh, for giving me invaluable guidance in the field of wireless sensor networks and providing me the opportunity to carry out this work further.It was the essential encouragement that enables me to pursuemy work in this field.

REFERENCES

[1] G. Anastasi, M. Conti, M. Di Francesco and A. Passarella, "How to Prolong the Lifetime of Wireless Sensor Networks," In: M. Denko and L. Yang, Eds., Mobile Ad Hoc and Pervasive Communications, American Scientific Publishers, CRC Press, Boca Raton, 2011.
[2] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless Sensor Networks: A Survey", Computer Networks, Vol. 38, No. 4, pp. 393-422, 2002.
[3] Deepak Goyal and Malay Ranjan Tripathy, "Routing Protocols in Wireless SensorNetworks: A Survey" Second International Conference on Advanced Computing&Communication Technologies, Year 2012
[4] G. Pottie, and W. Kaiser, "Wireless integrated network sensors," Communications of the ACM, Vol. 43, pp. 551–558, 2000.
[5] Ademola P. Abidoye, Nureni A. Azeez, Ademola O. Adesina and Kehinde K. Agbele,. A Novel Routing Algorithm for Energy Optimization in Wireless Sensor Networks. Research Journal of Information Technology, 4: 186-194, 2012.
[6] S.Lindsey and C. Raghavendra, "PEGASIS: power-efficient gathering in sensor information systems," in Proc. of IEEE Aerospace Conference, vol. 3, pp.1125–1130, March 9-16, 2002.
[7] F. Tang, I. You, S. Guo, M. Guo and Y. Ma, "A chain-cluster based routing algorithm for wireless sensor networks," Journal of Intelligent Manufacturing, vol. 23, Issue 4, pp. 1305-1313, August, 2012.
[8] R. Sheikhpour, S. Jabbehdari and A. khademzadeh, "A Cluster-Chain based Routing Protocol for Balancing Energy Consumption in Wireless Sensor Networks," International Journal of Multimedia and Ubiquitous Engineering, vol. 7, no. 2, pp. 1-16, April, 2012.
[9] R.Sheikhpour and S. Jabbehdari, "An Energy Efficient Cluster-Chain based Routing Protocol for 1378 Razieh Sheikhpour et al. An Energy Efficient Chain-based Routing Protocol for Wireless Sensor Networks Time Critical Applications in Wireless Sensor Networks," Indian Journal of Science and Technology, vol. 5, no. 5, pp. 2741-2749, May, 2012
[10] Razieh Sheikhpour, Sam Jabbehdari An Energy Efficient Chain-Based Routing Protocol For Wireless Sensor Networks In KSII Transactions On Internet And Information Systems Vol. 7, No. 6, June. 2013.